Early Results from DOE/NREL Transit Bus Evaluations

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APTA Bus and Paratransit Conference

Columbus, Ohio

May 17, 2005

NREL/PR-540-38158

Overview

- Background
- Early Results from New York City Transit
- Early Results from King County Metro
- Questions

NREL Fleet Test & Evaluation Team

- Evaluate “real world” performance of advanced propulsion technologies
- Focus on medium and heavy duty fleet applications
- Main goals:
  - Facilitate the transition of advanced technologies from the R&D stage into the marketplace
  - Provide potential fleet users with accurate and unbiased information on vehicle performance and costs
- Funding is provided by the Department of Energy’s Office of Energy Efficiency and Renewable Energy

Fleet Evaluation: Goals

- Objectives:
  - Assess status of new technologies in real-world service
  - Establish a benchmark of current and near-term technologies
  - Provide unbiased information on vehicle performance
  - Share lessons learned about implementation experience
- Target Audience:
  - Fleet managers considering use of the technology
  - Manufacturers & system integrators
  - Department of Energy
  - Other interested parties
    (APTA, FTA, EPA, EDTA…)

Fleet Evaluation: Specifics

Selection of Specific Technology and Site for Evaluation

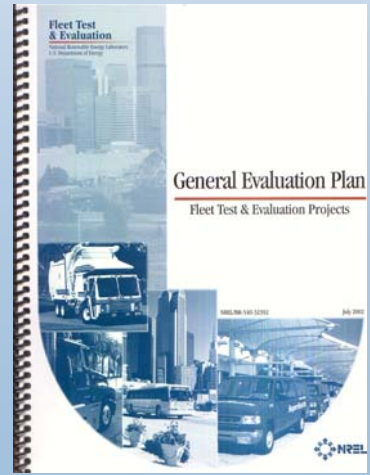
- Fuel and Technology Neutral
  - Alternative fuel - CNG, LNG, Biodiesel, LPG
  - Electric propulsion - hybrid-electric, fuel cell
- Site Selection Criteria include:
  - At least 5 advanced technology vehicles
  - Good record keeping
  - Motivated to participate

Fleet Evaluation: Specifics

Data collection plan based on existing and proven protocol developed for DOE heavy vehicle evaluations.

Data Collection includes:

- Vehicle specifications
- Vehicle expectations
- Vehicle usage and specific duty cycle
- Fuel and oil consumption
- Maintenance
- Fleet implementation experience
- Facility descriptions and capital cost



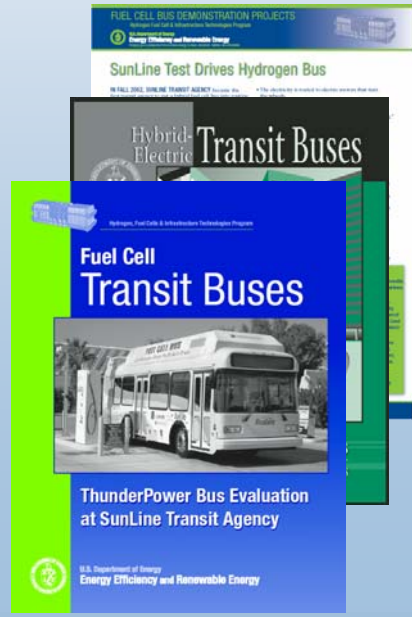
Fleet Evaluation: Specifics

Analysis and Reporting

The data collection typically covers one year of operation for both advanced vehicles and conventional comparison (if available).

Reports include:

- Two page fact sheet
- Early experience and results report
- Final Summary Report



Early Hybrid Bus Experience at NYCT in New York City

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Agenda

- Quick NYCT clean bus program description
- Plans for DOE/NREL evaluation
- Hybrid, Diesel, and CNG bus descriptions
- Early experience
- What's next

NYCT Clean Bus Program

NYCT Goals

- Reduce bus fleet emissions
- Improve service (reliability and noise)
- Reduce cost of operations (improve fuel economy and reduce costs)

NYCT Clean Bus Program

- Repowering old 2-stroke diesel engines to new EGR-equipped 4-stroke diesel engines; to be completed in 2005
- All diesel engines to be equipped with diesel particulate filters (in progress)
- CNG buses – 481 in operation
- Hybrid buses – 325 in operation by mid-2005

NYCT Reasons for Hybrid Buses

- Emissions reductions
- Increased fuel economy
- Smooth and quiet operation
- Improved performance
- Avoids infrastructure costs of CNG

CNG and Hybrid Buses

Depot	CNG (260)	Hybrid (125)	Hybrid (200)
Gleason	95		
West Farms	165		
Mother Clara Hale		60	
Queens Village		65	
Fresh Pond			135
Manhattan-ville			65

Planned DOE/NREL Evaluation

- **Hybrid Order of 125 Orion VII Buses - 10 Hybrid Buses at Mother Clara Hale Depot in Manhattan Division** (10 Orion V diesel buses chosen for comparison) – Average speed at depot of 6.5 mph

Planned DOE/NREL Evaluation

- **CNG Order of Orion VII Buses – 10 CNG Buses at West Farms Depot in Bronx Division** (10 NovaBus RTS diesel buses chosen for comparison) – Average speed at depot of 6.5 mph

Planned DOE/NREL Evaluation

- **Hybrid Order of 200 Orion VII Buses – 10 Hybrid Buses at Fresh Pond Depot** (10 diesel buses to be chosen for comparison)

Planned DOE/NREL Evaluation

- Collect and analyze operations data (bus usage, fuel, and maintenance) for 12 months
- Order of 125 Hybrid buses and CNG bus evaluations starting with October 2004
- Hybrid Order of 200 evaluation just getting underway

Vehicle Descriptions

System	Hybrid (125)	CNG
Bus	Orion VII 40’	Orion VII 40’
Engine	Cummins ISB 270 hp 660 ft-lb	DDC S50G 275 hp 900 ft-lb
Emissions	4.0 g/bhp-hr NOx; 0.05 g/bhp-hr PM using a DPF	2.5 g/bhp-hr NOx+HC; 0.05 g/bhp-hr PM without Cat

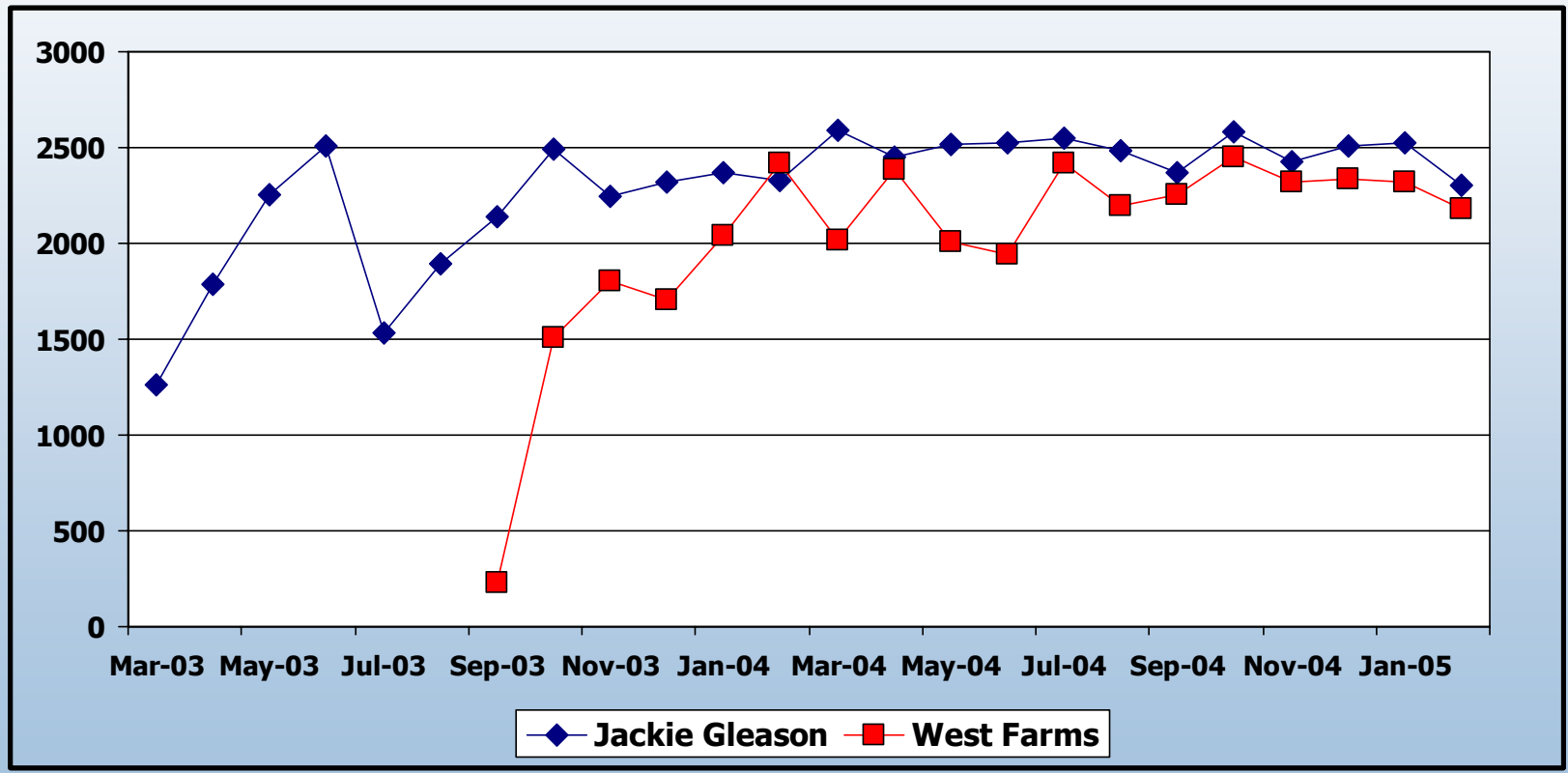
Vehicle Descriptions

System	Hybrid (125)	CNG
Electric Propulsion	BAE SYSTEMS HybriDrive™	None
Energy Storage	Sealed lead acid	None
Regenerative Braking	Yes	None

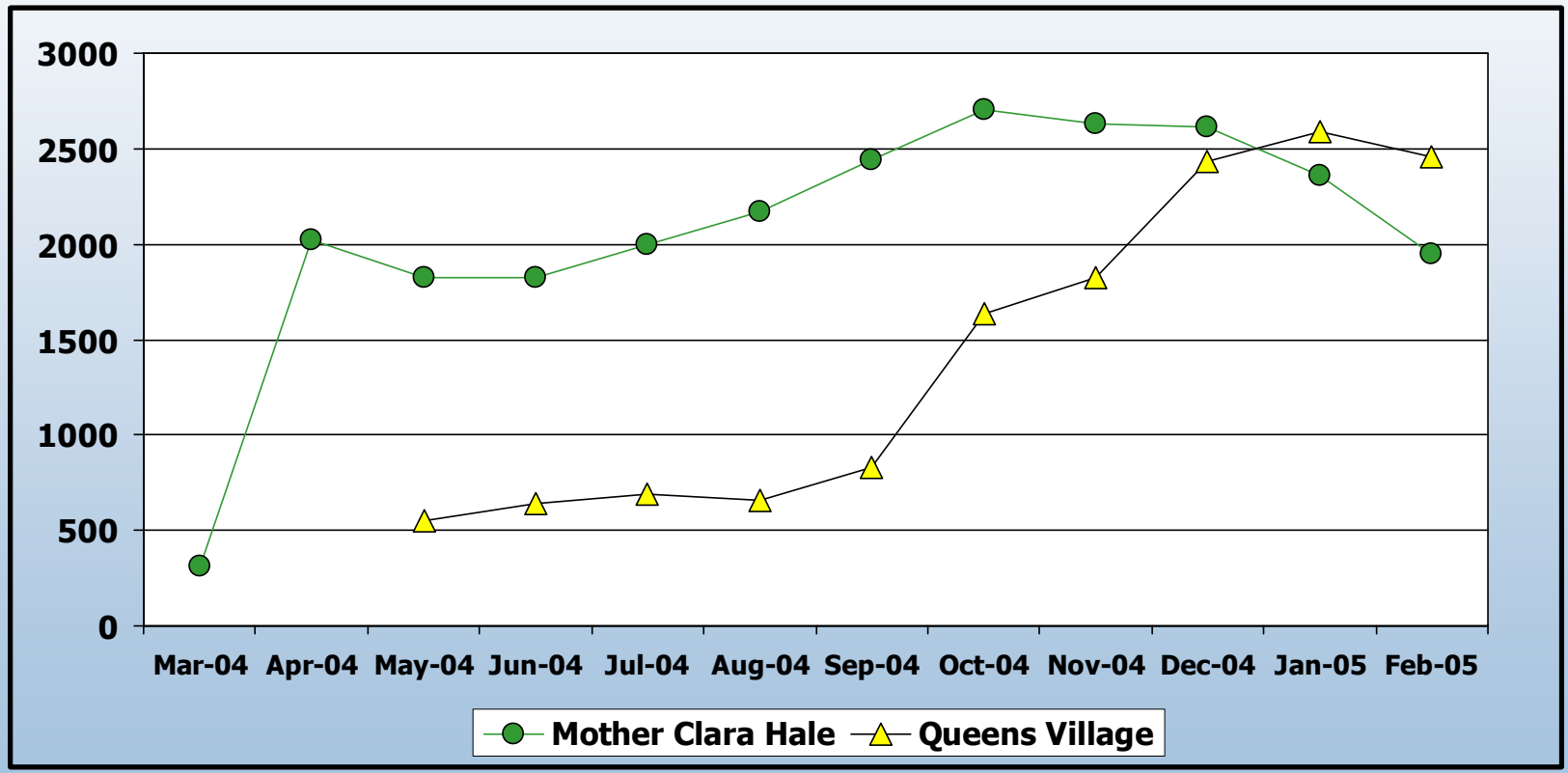
Early Experience

- CNG Orion VII buses started arriving at NYCT in March 2003
- West Farms started getting their first CNG Orion VII buses in September 2003
- Hybrid buses started operation at Mother Clara Hale Depot in March 2004
- Hybrid buses started operation at Queens Village Depot in May 2004

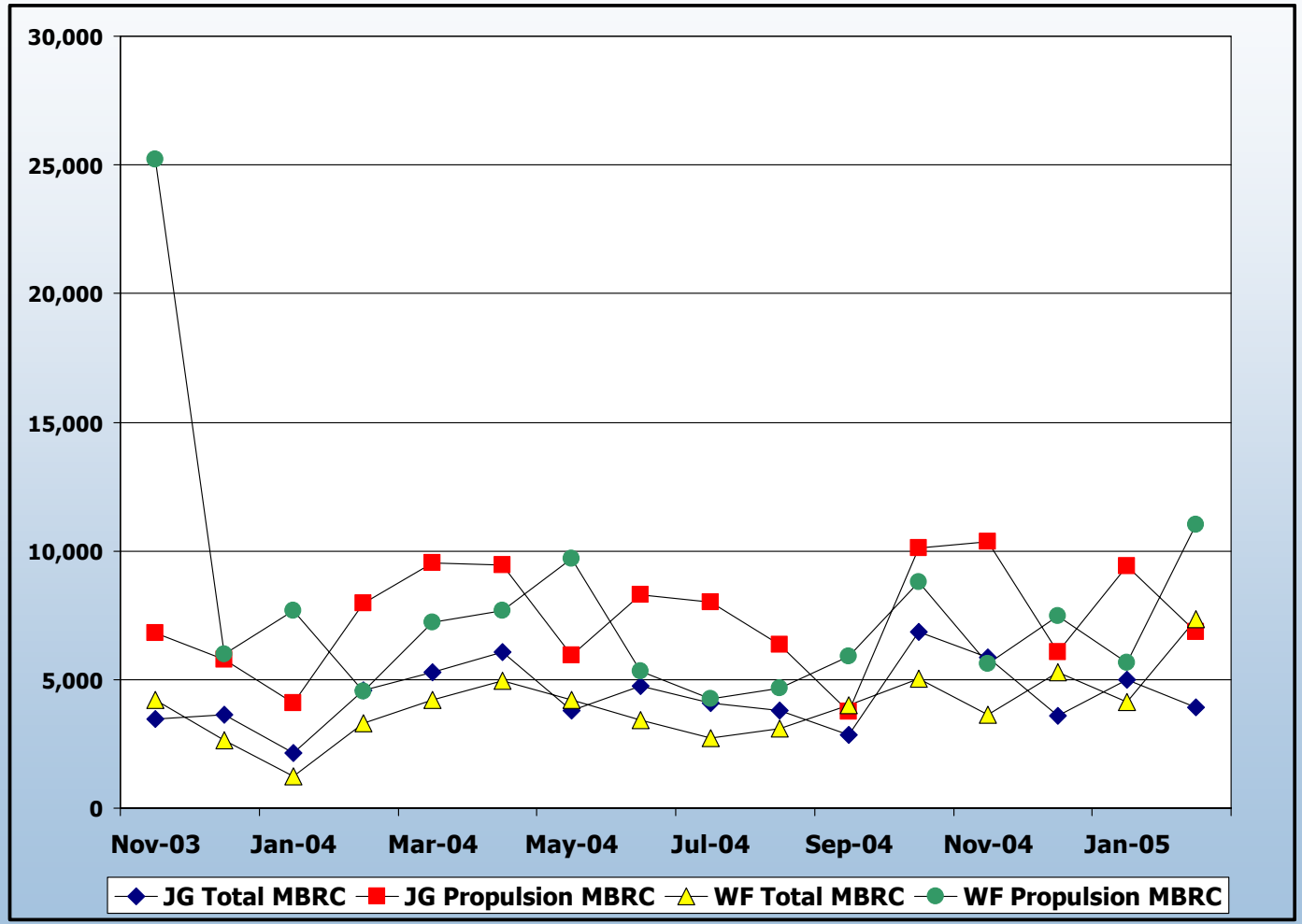
Average Monthly Mileage per Bus
CNG Buses



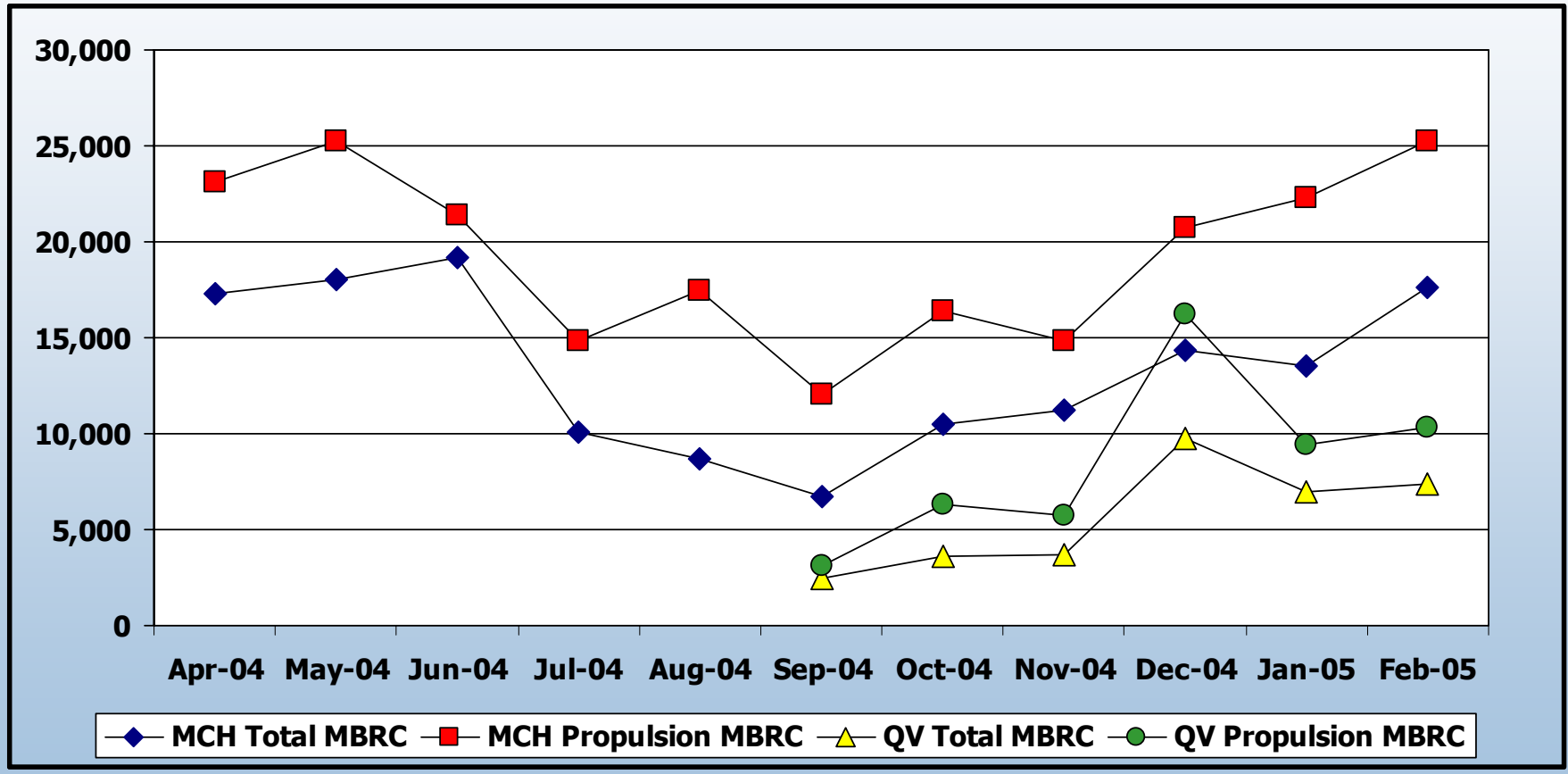
Average Monthly Mileage per Bus
Hybrid Buses



Miles Between Roadcalls (MBRC)
CNG Buses



Miles Between Roadcalls (MBRC)
Hybrid Buses



Fleet Campaigns – Orion VII CNG and Hybrid

Bus

- Axle bolts coming loose
- Radiator baffle, surge tank overflowing
- Fuel lift pump
- Fuel injection pump
- PCS cooling pump seizure
- Water in wiring/connectors
- Engine grid heater relay
- Water in engine from air intake

Hybrid

- PCS internal coolant leaks
- PCS board modification
- Software upgrade

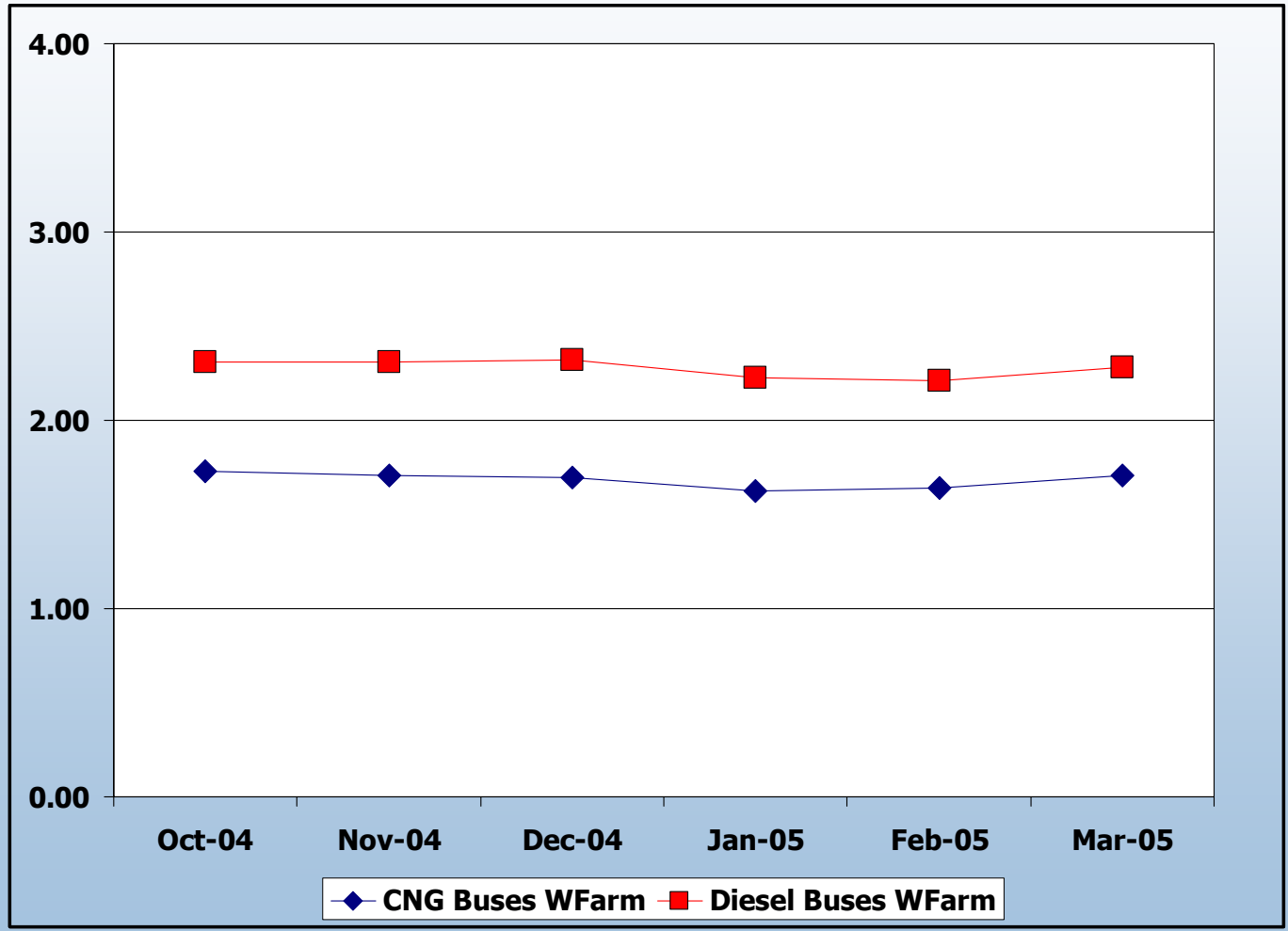
CNG

- Cylinder kits
- Spark plugs

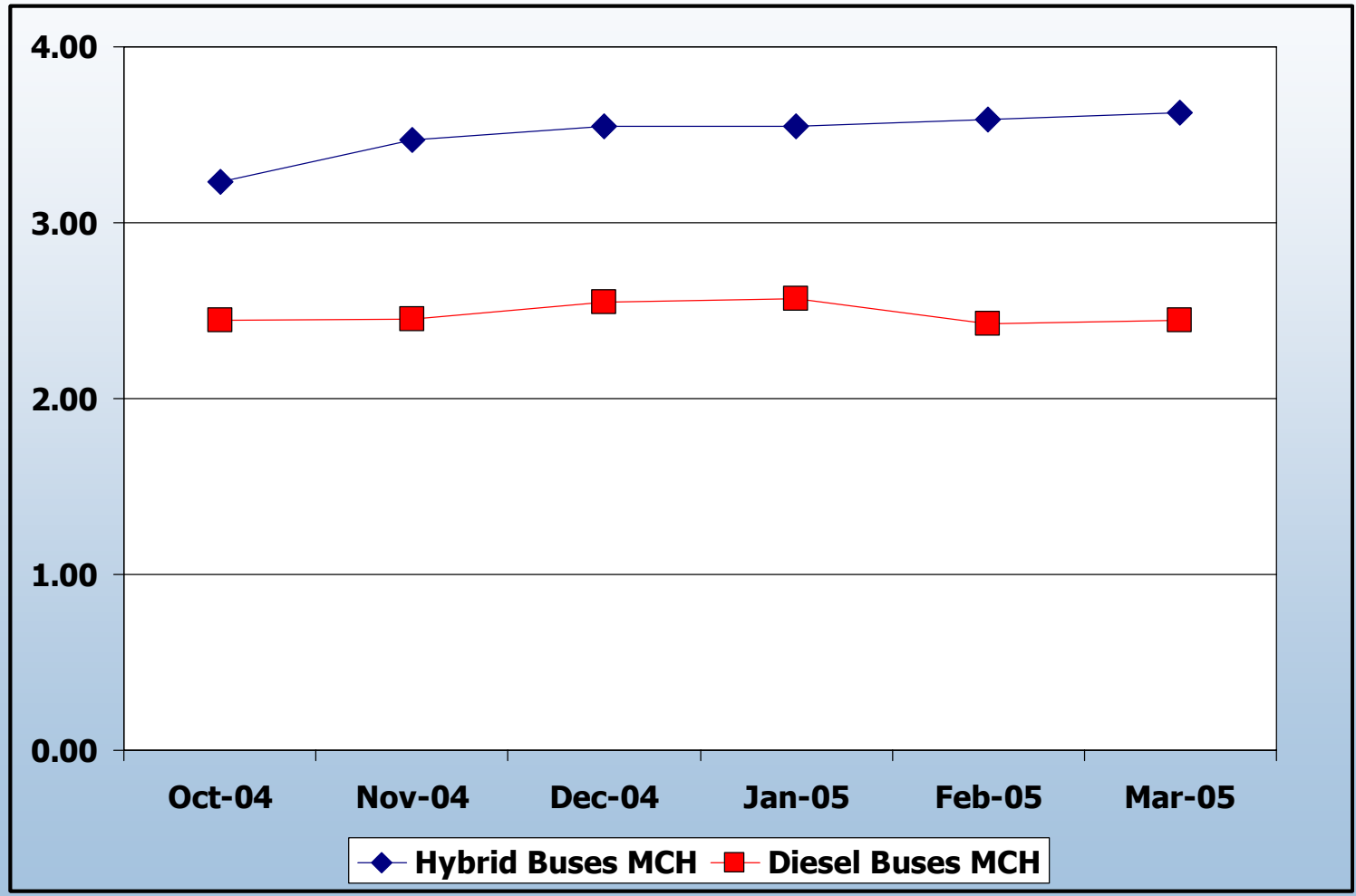
Early Results for Evaluation Buses

- Data period for results that follow:
  - West Farms Depot, 10/04-3/05
  - Mother Clara Hale Depot, 10/04-3/05
- The following information represents early experience, NOT final results

Early Results for Evaluation Buses Fuel Economy – CNG and Diesel



Early Results for Evaluation Buses Fuel Economy – Hybrid and Diesel



What's Next

- Complete DOE/NREL evaluation - 12 months of operations for the Hybrid order of 125 and CNG buses starting October 2004
- Evaluation of Hybrid order of 200 just getting under way
- Reports
  - Fact sheet available
  - Interim report planned for Fall of 2005
  - Final report planned for mid-2006

Special Thanks

- New York City Transit
- Orion Bus
- BAE SYSTEMS
- U.S. Department of Energy

Early Hybrid Bus Experience at KC Metro in Seattle, WA

Kevin Chandler
Battelle

Agenda

- Quick KC Metro hybrid program description
- Hybrid and Diesel bus descriptions
- Early experience
- Plans for DOE/NREL evaluation
- What's next

King County Metro Hybrid Bus Program

- Purchased 235 New Flyer/Allison Electric Drive articulated buses (October 2003) - $645,000 each
- Hybrid buses replacement for Breda dual-mode buses being retired
- Also purchased 30 diesel New Flyer articulated buses at the same time - $445,000 each
- Sound Transit received 22 hybrid (of the 235 buses) and 16 diesel articulated buses, all operated by KC Metro

Vehicle Descriptions

System	Diesel	Hybrid
Bus	New Flyer 60’	New Flyer 60’
Engine	Caterpillar C9 330 hp 1150 ft-lb	Caterpillar C9 330 hp 1150 ft-lb
Emissions	2.5 g/bhp-hr NOx+HC; 0.05 g/bhp-hr PM using a DPF	2.5 g/bhp-hr NOx+HC; 0.05 g/bhp-hr PM using a DPF

Vehicle Descriptions

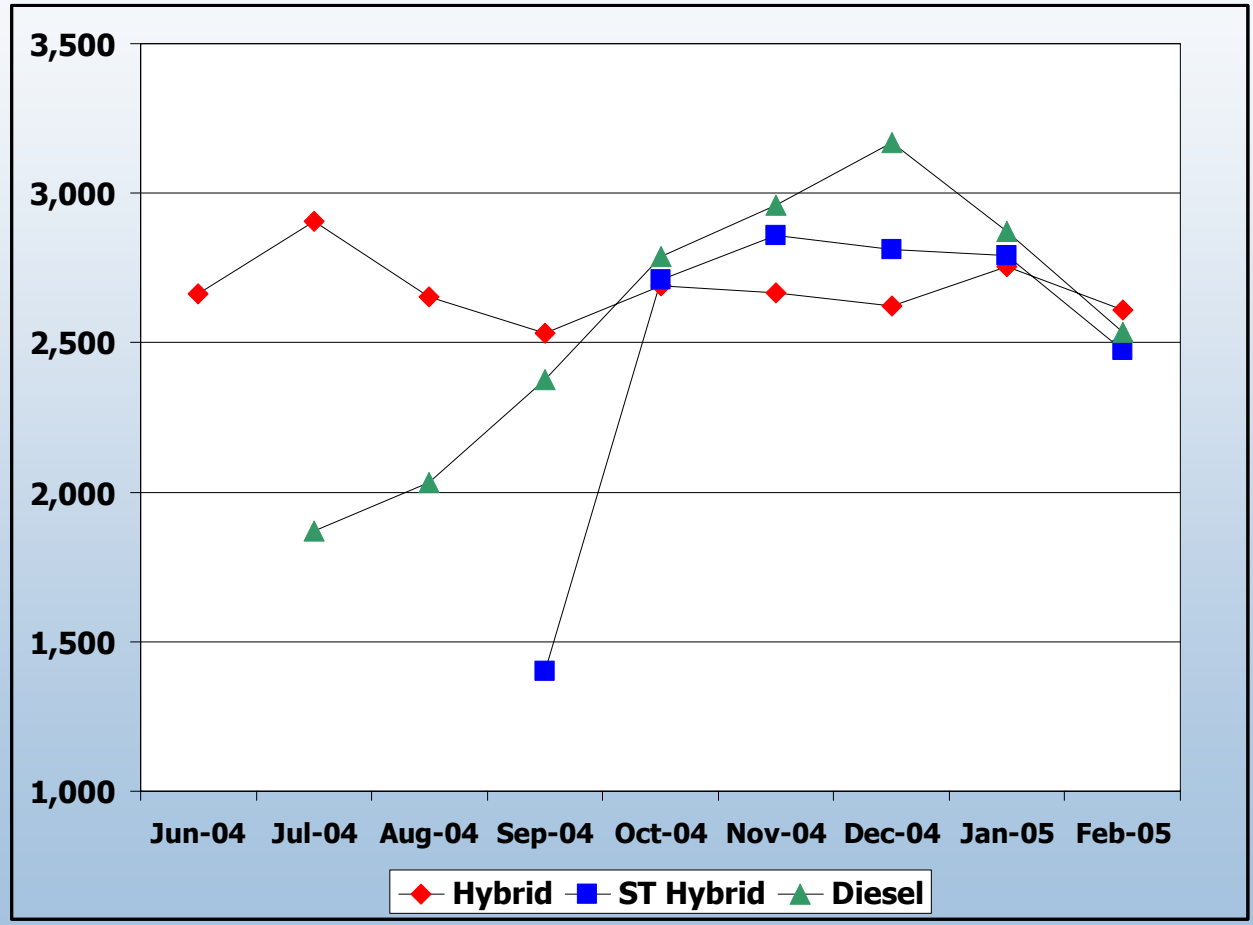
System	Diesel	Hybrid
Electric Propulsion	None	Allison E^P50 Parallel Hybrid System
Energy Storage	None	Nickel metal hydride batteries
Regenerative Braking	None	Yes

New Flyer Articulated Buses at KC Metro

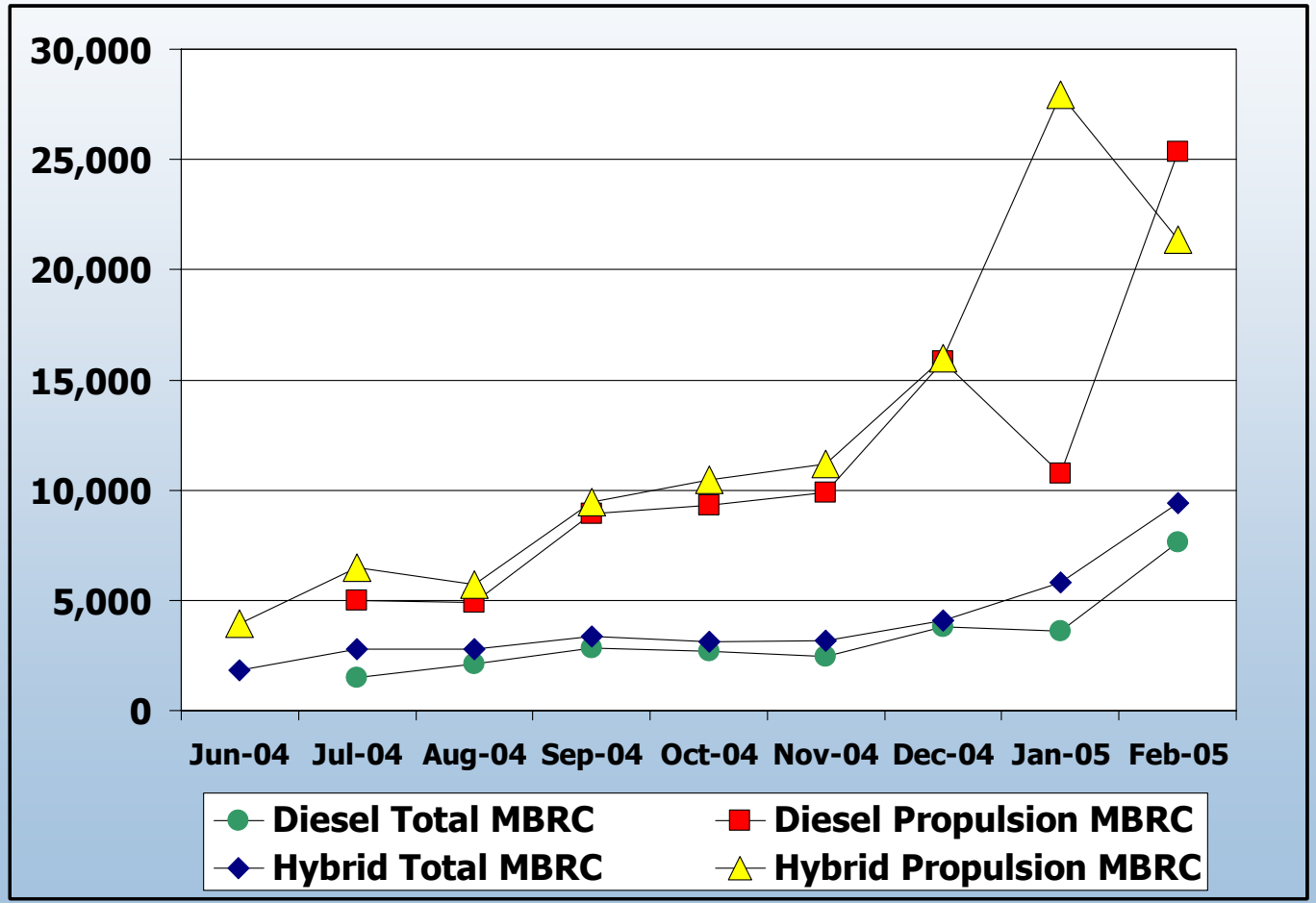
Early Experience

- Introduction of 235 hybrid buses started in June 2004 and was completed by December 2004
- Hybrid buses reported as easy to put into service within 2-3 days after delivery
- By end of February 2005, fleet have completed ~4 million miles (~6 million miles as of today)

Average Monthly Mileage per Bus



Roadcalls


30,000
25,000
20,000
15,000
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0
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Diesel Total MBRC
Diesel Propulsion MBRC
Hybrid Total MBRC
Hybrid Propulsion MBRC

Fleet Campaigns

- Axle snap rings – 8/04
- Soot filter replacement – 8/04
- Communication modules – 8/04
- Allison/CAT software upgrade – 9/04
- Door proximity switches – 10/04
- Center axle radius rod bolts – 11/04
- Wire chaffing over rear door – 12/04
- Master switch – 12/04
- Mirror drain holes – 1/05

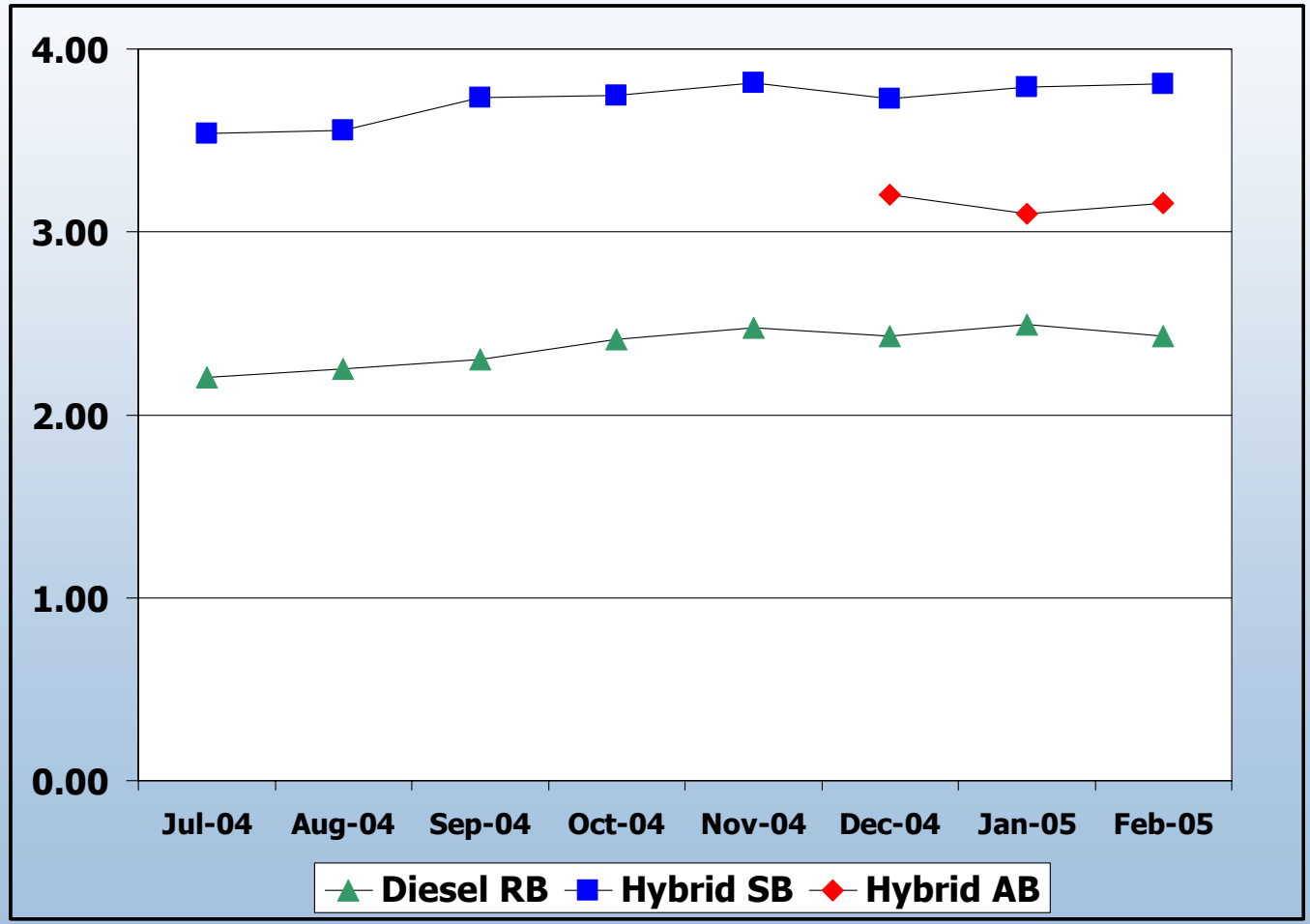
Planned DOE/NREL Evaluation

- **10 Hybrid Buses at Atlantic Base** (best match in operation compared to diesel buses) – Average speed of 11.2 mph
- **10 Hybrid Buses at South Base** (first base to put hybrids into service) – Average speed of 19.2 mph
- **10 Diesel Buses at Ryerson Base** – Average speed of 13.3 mph
- Collect and analyze operations data (bus usage, fuel, and maintenance) for 12 months starting with April 2005

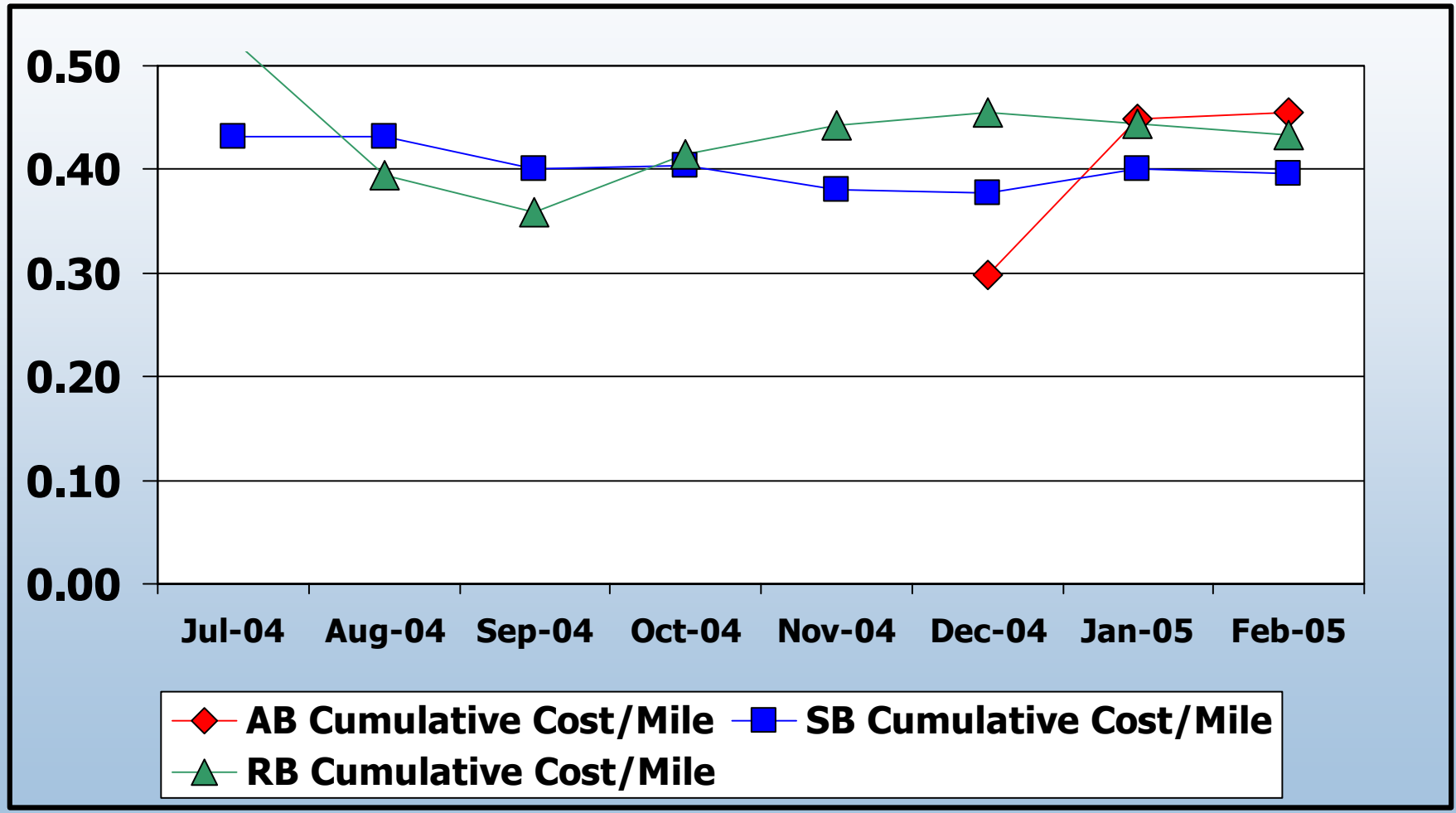
Early Results for Evaluation Buses

- Data period for results that follow:
  - South Base Hybrids, 7/04-2/05
  - Atlantic Base Hybrids, 12/04-2/05
  - Ryerson Base Diesels, 7/04-2/05
- The following information represents early experience, NOT final results

Early Results for Evaluation Buses Fuel Economy



Early Results for Evaluation Buses Maintenance Costs per Mile



Early Results for Evaluation Buses Fuel and Maintenance Cost/Mile

	Diesel RB	Hybrid AB	Hybrid SB
Fuel ($1.47/gal)	$0.614/mi 2.39 mpg	$0.466/mi 3.15 mpg	$0.396/mi 3.72 mpg
Maintenance	$0.433/mi	$0.456/mi	$0.396/mi
Total	$1.047/mi	$0.922/mi	$0.791/mi

What's Next

- Complete DOE/NREL evaluation - 12 months of operations for the 30 study buses starting April 2005
- Chassis Dynamometer Emissions Testing
- Reports
  - Fact sheet available
  - Interim report planned for end of 2005
  - Final report planned for mid-2006

Special Thanks

- King County Metro
- New Flyer
- Allison Electric Drives
- Caterpillar
- U.S. Department of Energy